INDOOR AIR QUALITY ASSESSMENT

Williamsburg Town Office Building
147 Main Street
Williamsburg, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Maxine Schmidt, Health Agent of the Foothills Health District, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Williamsburg Town Office Building (WTOB), 147 Main Street, Williamsburg, Massachusetts. Concerns about odors detected around the front door/foyer prompted the request. On August 15, 2002, a visit was made to this building by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment. Ms. Schmidt accompanied Mr. Feeney during the assessment.

The WTOB is a two-story, wood clapboard exterior structure originally constructed as a school. The building was renovated during the 1970s and converted into town offices. The second floor was unoccupied at the time of the assessment. The first floor currently has town offices. The basement is reportedly unoccupied and is used for storage. Of note is the large number of plumbing fixtures in the basement that were used for restrooms and food service when the building was a school. An attic/crawlspace exists beneath the roof.

Windows are openable throughout the building. Windows appear to be original wooden sash windows.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551.

Results

The WTOB has an employee population of 6 and is visited by approximately 25 to 30 people daily. Tests were taken during normal operations and results appear in Tables 1-2.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were above 800 parts per million of air (ppm) in all occupied offices, indicating a ventilation problem in the building. Please note that rooms with carbon dioxide levels below 800 ppm either had open windows/doors or were unoccupied. Carbon dioxide levels in the building would be expected to be higher during winter months, when windows are closed, due to the configuration and condition of the ventilation system.

Fresh air ventilation was originally provided by unit ventilators (univents). Univents draw fresh air from a vent on the exterior of the building and air from the room (called return air) through a vent in the base of the unit (see Figure 1). Fresh air and return air are mixed, filtered, heated and provided to rooms through a fresh air diffuser located in the top of the unit. With the deactivation of the univents, the sole source of fresh air into the interior of the building is through openable windows.

Exhaust ventilation is drawn from the classroom into an ungrated hole located at floor level (see Picture 1). No airflow was detected in any of the exhaust vents examined. A louver located inside the duct controls airflow. Above the louver is usually a heating element that creates airflow via rising heat called "the stack effect". It is possible that exhaust air is removed from the building by a deactivated fan/motor located in a cupola in the roof (see Picture 2). Examination of the ductwork in the attic found it cut in half and sealed with a plywood plug (see Pictures 3 and 4). The abandonment of the exhaust vents essentially prevents air from exhausting from the building. A potential source of odors is a restroom that was added on the first floor. It appears that the exhaust vent for this restroom was cut into the existing exhaust vent that was sealed in the attic. This configuration would direct exhaust air into the ductwork, which would then have the potential to migrate into town offices through existing exhaust vents when the restroom fan is activated. Under these circumstances, it appears that the building does not have a functioning exhaust ventilation system. Without exhaust ventilation, normally occurring environmental pollutants can build up and lead to air quality/comfort complaints.

During summer months, ventilation was originally controlled by the use of openable windows in classrooms. The building was configured in a manner to use cross-ventilation to provide comfort for building occupants. The WTOB is equipped with windows on opposing exterior walls. In addition, hinged windows are located above the hallway doors. This hinged window (called a transom) enables the occupant to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through a room, pass through the open transom, enter the hallway, pass through the opposing room's open transom, into the opposing room and exit the building on the leeward side (opposite the windward side) (see Figure 2). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. The system fails if the windows or transoms are closed (see Figure 3). Each room would have a long pole with a hook that was used to open the hoop latch that locks the transom closed. Most transoms were permanently sealed during a previous renovation, which can inhibit airflow in the summer if hallway doors are closed. In addition, open windows may also allow for rainwater to penetrate through windows. Pests such as bats and insects also have access to the interior if windows are left open overnight (see **Other Concerns** section of this report).

An abandoned exhaust ventilation fan system was located in the basement (see Picture 5). The purpose of this system originally removed odors and water vapor from the abandoned restrooms in the basement.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). Please note that the ventilation systems, in its condition at the time of the assessment, cannot be balanced.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix I.

Temperature readings ranged from 73^{o} F to 84^{o} F, which were above the BEHA recommended comfort guidelines in a number of areas. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is difficult in an old building without a functioning ventilation system.

The relative humidity ranged from 43 to 48 percent in occupied areas, which was below the BEHA recommended comfort range (see Tables). The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. It is important to note however, that relative humidity measured in the basement and the second floor exceeded outdoor measurements (range +6 to 10 percent). This increase in relative humidity can indicate that the exhaust system is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration). Moisture removal is important since the sensation of heat increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperatures rise, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is increased. Removal of moisture from the air, however, can have some negative effects. Please note relative humidity in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

During the spring and summer of 2002, New England experienced a stretch of excessively humid weather during three periods in May, July and August. As an example, outdoor relative humidity at various times ranged from 73 percent to 100 percent without precipitation from July 4, 2002 through July 12, 2002 (The Weather Underground, 2002). According to the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), if relative humidity exceeds 70 percent, mold growth may occur due to wetting of building materials (ASHRAE, 1989).

The basement is used for storage of large amounts of materials, including cardboard and paper products (see Picture 6). If these materials are subjected to high relative humidity conditions without drying for several days, it is likely that these materials can become colonized by fungi (mold). A noted previously, relative humidity measurements in the basement were 10 percent higher than the relative humidity measured outdoors (54%). Increased temperature indoors, as measured in this building, would be expected to have lower relative humidity compared to outdoors. The increase in relative humidity may indicate that a moisture source exists in the building. Several possibilities were examined:

1. One possible source of increased relative humidity is occupants in a building without adequate air exchange. This possibility was ruled out since the basement was unoccupied.
2. As noted previously, the sole means for venting the basement was deactivated. While efforts were made to seal restroom drains, a number of drains exist in the building that can be sources of water vapor.
3. Shrubbery exists in close proximity to the foundation walls (see Picture 7). The growth of roots against the exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Over time, this process can undermine the integrity of the building

envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek, J. & Brennan, T.; 2001).

Each of these conditions, in combination with high ambient temperature during the summer, increased relative humidity and possible water sources within the basement, may contribute to moistening of porous materials. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials (e.g., carpet) be dried with fans and heating within 24 hours of becoming wet (US EPA, 2001, ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur.

In order to explain how mold and associated odors/particulates in the basement can migrate into occupied areas, the following concepts must be understood:

- Heated air (from radiators) will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- As the heated air rises, negative pressure is created, which draws cold air to the heat source.
- Airflow created by the stack effect, drafts or mechanical ventilation can draw airborne particulates into the air stream (i.e. from the basement).
- The opening of the door to the basement at the base to the main stairwell can provide a pathway for air to travel from the basement to the upper floors.

Each of these concepts has an influence on the movement of basement odors or other particulates up the stairwell. In order to control possible mold growth, water penetration into the basement area must be minimized. Control of water penetration through the foundation can be limited by removing plants from close proximity to the exterior walls of the WTOB.

Other Concerns

Building occupants reported that the odor appeared to be located around the front door foyer. Building occupants could not identify whether this odor was located inside or outside the front door. Two potential sources exist within the building as possible odor sources: unused basement plumbing or the abandoned rainwater gutter/downspout system.

As previously mentioned, a number of former sinks/floor drains exist in the basement (see Picture 8). These drains did not appear to have recently drained water, which can lead to dry traps. A trap forms an airtight seal when water is poured down the drain. A dry trap can allow for sewer gas to back up into the building. These odors can then migrate up the stairwell in the same manner as described in the **Microbial/Moisture Concerns** Section of this report.

It appears that a new drainage system was installed for the roof gutters (see Picture 9) and that the original system was connected to pipes within holes in the exterior wall of the building (see Picture 10). Each original downspout drainpipe passes through the foundation and enters the floor of the basement (see Picture 11), presumably to the sewer/storm water system. If the air pressure within the sewer/storm water system increases due to a heavy water flow, odor can now be forced out from the original downspout system at ground level. Sewer gas can be irritating to the eyes, nose and throat. It is possible that both the basement drains and the original downspout system can emit odors, particularly during or after rainstorms.

Filters in window-mounted air conditioners had significant amounts of accumulated dust and debris. The purpose of air conditioner filters is to remove particulate matter from air drawn into the units. Air conditioner filters need to be cleaned on a regular basis in order to maximize the efficiency of the filter. If not cleaned regularly, the filter can become saturated with dust and become a source of aerosolized particulates when the air conditioner is operating. In order to reduce particulate aerosolization, filters should be cleaned or changed in a manner consistent with the air conditioner manufacturer's recommendations.

While in the attic, Mr. Feeney detected the squeaking of roosted bats. Bats in a building raise concerns over diseases that may be caused by exposure to bat wastes. These conditions warrant clean up of bat waste and appropriate disinfection. Certain molds (*Histoplasma capsulatum)* are associated with bat waste (CDC, 2001; NIOSH, 1997) and are of concern for immune compromised individuals. Diseases of the respiratory tract may also result from exposure to bat waste. While immune compromised individuals have an increased risk of health impacts following exposure to the materials in bat wastes, these impacts may also occur in healthy individuals exposed to these materials.

The methods to be employed in clean up of a bat waste problem depends on the amount of waste and the types of materials contaminated. The MDPH has been involved in several indoor air investigations where animal waste has accumulated within ventilation ductwork. Accumulation of bat wastes have required clean up of such buildings by a professional cleaning contractor. In less severe cases, the cleaning of the contaminated material with a solution of sodium hypochlorite has been an effective disinfectant (CDC, 1998). Disinfection of non-porous materials can be readily accomplished with this material. Porous materials contaminated with bat waste should be examined by a professional restoration contractor to determine if the material is salvageable. Where a porous material has been colonized with mold, it is recommended that the material be discarded (ACGIH, 1989).

The building also shows signs of rodent infestation. A dead mouse was found floating in water of the sump pump. Rodent infestation can result in indoor air quality related symptoms due to materials in their wastes. Mouse urine is known to contain a protein that is a known sensitizer (US EPA, 1992). A sensitizer is a material that can produce symptoms in exposed individuals (e.g., running nose or skin rashes). A three-step approach is necessary to eliminate rodent infestation:

- removal of the rodents;
- cleaning of waste products from the interior of the building; and
- reduction/elimination of pathways/food sources that are attracting rodents.

To eliminate exposure to allergens, rodents must be removed from the building. Please note that removal, even after cleaning, may not provide immediate relief since allergens can exist in the interior for several months after rodents are eliminated (Burge, H.A., 1995). A combination of cleaning, increase in ventilation and filtration should serve to reduce rodent associated allergens once the infestation is eliminated.

As originally installed, univents were not provided with a means to install filters. Without filters, particles can become aerosolized. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent through increased resistance (called pressure drop). Prior to any increase of filtration, univents should be evaluated by a ventilation engineer to ascertain whether they can maintain function with (more efficient) filters.

Spaces around pipes were noted within all univent cabinet interiors surveyed. Open pipes and spaces around pipes can serve as pathways for dust, dirt, odors and other pollutants to move from the floor/wall cavities into occupied areas during the operation of univents.

A photocopier is located in the main office. Volatile organic compounds (VOCs) and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992). Local exhaust ventilation may be needed in this area to help reduce excess heat and odors.

Conclusions/Recommendations

The renovations to the ventilation system in the building essentially removed any means to provide exhaust ventilation. This minimization of air exchange can result in environmental pollutants concentrating in occupied areas.

In order to address the conditions listed, the recommendations made to improve indoor air quality in the building are divided into short-term and long-term corrective measures. The **short-term** recommendations can be implemented as soon as practicable. **Long-term** solution measures are more complex and will require planning and resources to adequately address the overall indoor air quality concerns.

Short Term Recommendations

1. Seal the original downspout pipes in the exterior walls of the building.
2. Keep the stairwell door to the basement closed. Install weather stripping and a door sweep on this door to create an airtight barrier.
3. Seal all abandoned drains in the basement. Disconnected water supplies to sealed drains.
4. Repair the restroom exhaust vent system in the basement. Once repaired, operate the system to remove water vapor from the basement.
5. Ascertain whether the first floor restroom vent is connected into the general exhaust vent system. If connected to the general exhaust system, disconnect to prevent odor migration throughout the building. If connected to the duct for the basement restroom vent, leave this connection intact.
6. To prevent moisture penetration into the basement, the following actions should be considered:

a) Remove foliage to no less than five feet from the foundation.

b) Improve the grading of the ground away from the foundation at a rate of 6 inches per every 10 feet (Lstiburek, J. & Brennan, T.; 2001).

c) Install a water impermeable layer on ground surface (clay cap) to prevent water saturation of ground near foundation (Lstiburek, J. & Brennan, T.; 2001).

7. Remove bats from attic/roof structures. Install bird screens on roof top cupola if missing. Install a roof cap on chimney to prevent bat entry.

8. Seal all holes in the exterior walls of building to prevent mouse and other rodent migration.

9. Remove mold colonized materials from the basement. Disinfect non-porous surfaces with an appropriate antimicrobial.

10. Render airtight all holes/seams in univents.

11. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

12. Consider installing local exhaust ventilation in the photocopier area.

13. Discard dead mouse from sump pump.

14. It is highly recommended that the principles of integrated pest management (IPM) be used to rid the building of pest. A copy of the IPM recommendations can be obtained from the Massachusetts Department of Food and Agriculture (MDFA) website at the following website: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf. Activities that can be used to eliminate pest infestation may include the following activities.

a) Rinse out recycled food containers. Seal recycled containers in a tight fitting lid to prevent rodent access.
b) Remove non-food items that rodents are consuming.
c) Stored foods in tight fitting containers.
d) Avoid eating at workstations. In areas were food is consumed, periodic vacuuming to remove crumbs are recommended.
e) Regularly clean crumbs and other food residues from toasters, toaster ovens, microwave ovens coffee pots and other food preparation equipment;
f) Holes as small as ¼" are enough space for rodents to enter an area. Examine each room and the exterior walls of the building for means of rodent egress and seal . If doors do not seal at the bottom, install a weather strip as a barrier to rodents.
g) Reduce harborages (cardboard boxes) where rodents may reside.

Long Term Recommendations

1. Prior to any upgrade to mechanical systems, consideration should be given to upgrading the electrical service and related wiring in the building. Installation of new ventilation equipment may require more electrical power than the current system can provide.
2. Consideration should be given to repairing the original exhaust ventilation system. Consult a ventilation engineer to determine whether existing ductwork can be restored.
3. Consult a ventilation engineer to determine whether existing univents can be retrofitted with a means to provide fresh air and filtration. If not feasible, consideration should be given to replace the existing univent system.

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http://www.wunderground.com/history/airport/KBAF/2002/7/11/DailyHistory.html
http://www.wunderground.com/history/airport/KBAF/2002/7/12/DailyHistory.html

Figure 2 **Cross Ventilation in a Building Using Open Windows and Transoms/Open Hallway Doors**

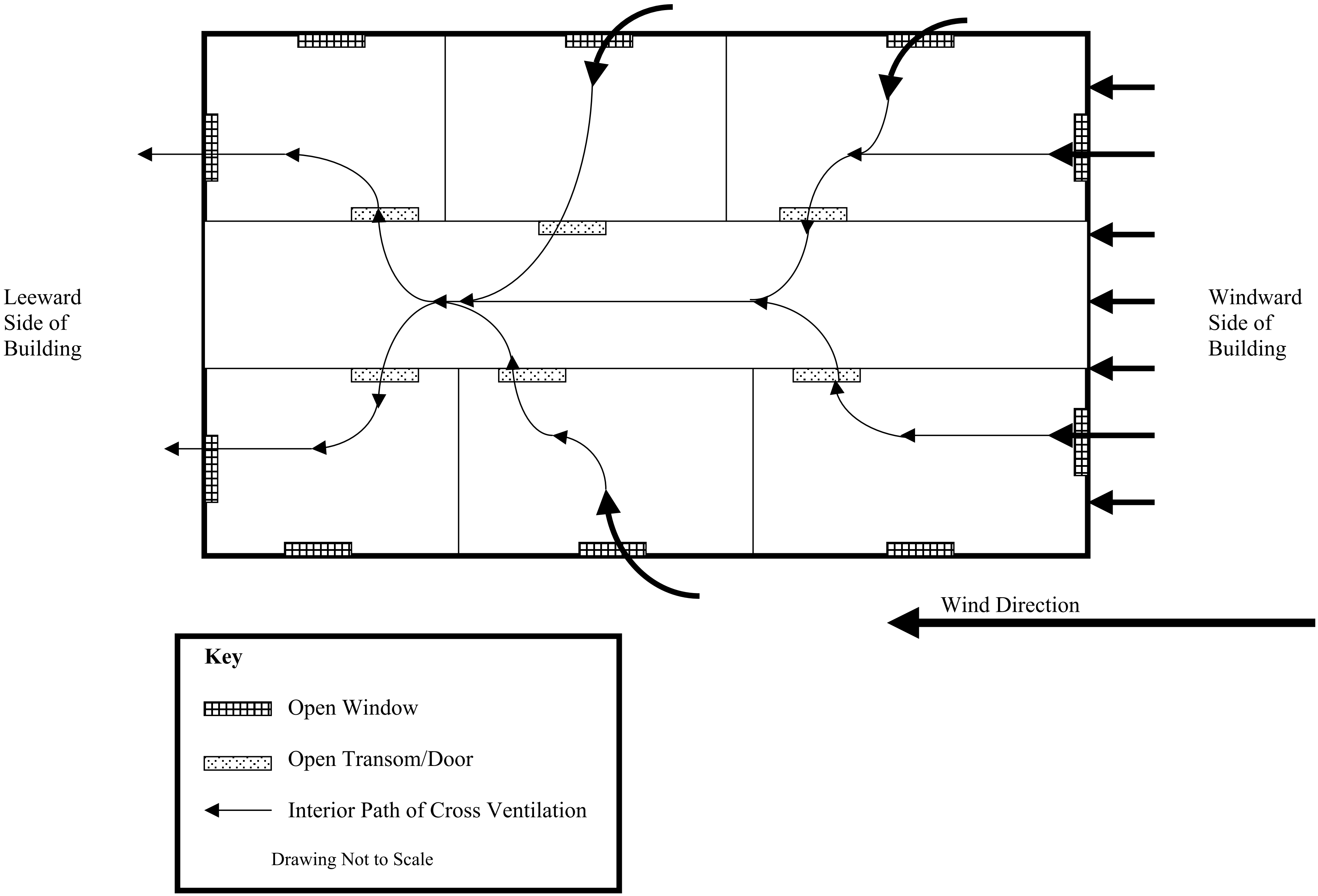
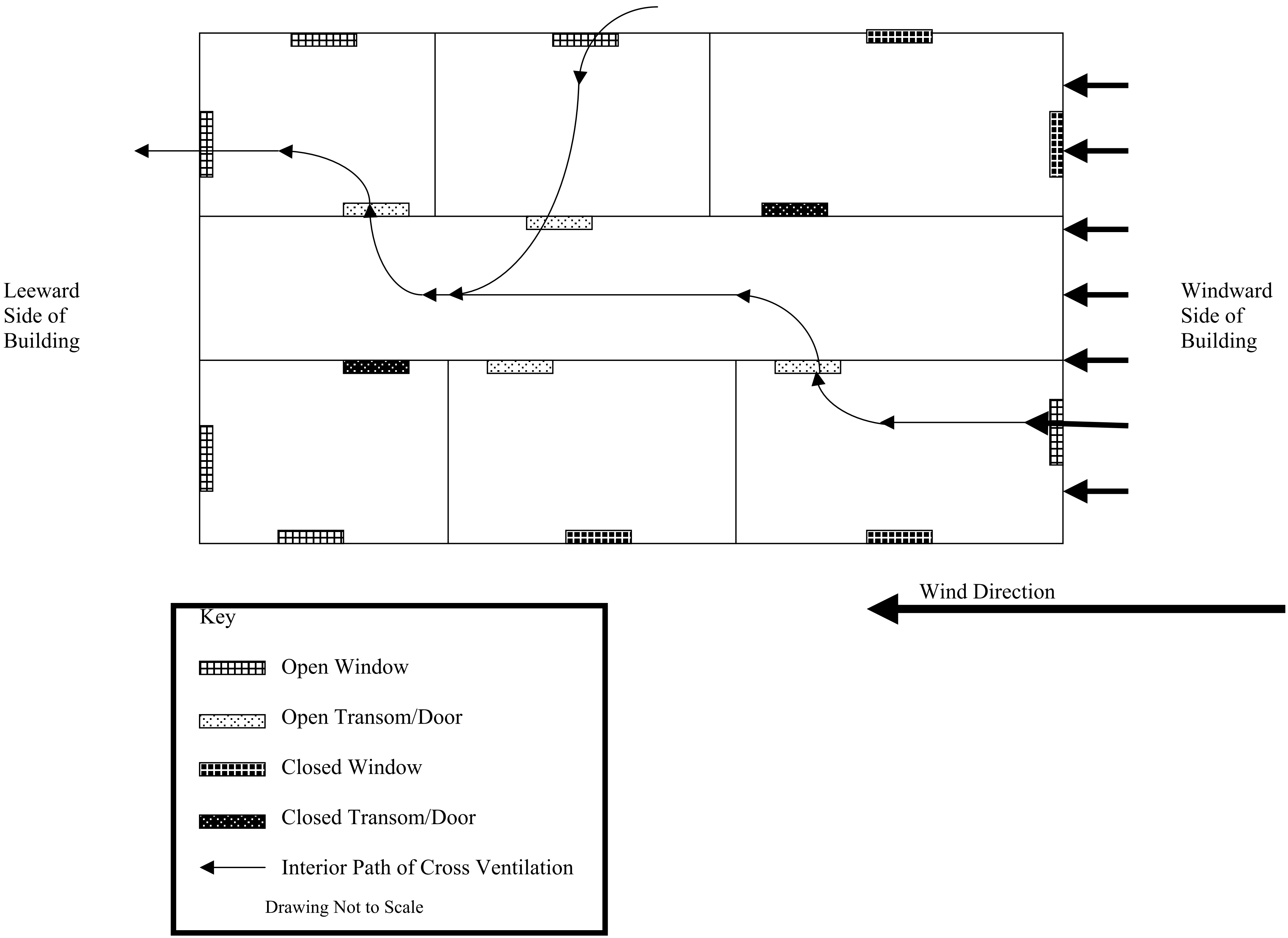


Figure 3 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms/Open Hallway Doors**



Picture 1

Exhaust Vent, Note Louver Lever Above Vent

Picture 2

Cupola On Roof, Note Lack Of Chimney Cap

Picture 3

Duct Cut Apart And Sealed With Plywood

Picture 4

Duct Cut Apart And Sealed With Plywood

Picture 5

Restroom Exhaust Vent In Basement

Picture 6

Materials Stored In Basement

Picture 7

Shrubbery In Close Proximity To Basement

Picture 8

Abandoned Sink In Basement

Picture 9

New Downspout Connection For Roof Drainage System, Note Hole For Pipe Of Original Downspout

Picture 10

Hole For Pipe Of Original Downspout In Foundation

Picture 11

Pipes In The Basement Connected To Original Downspout System

TABLE 1

Indoor Air Test Results – Williamsburg Town Offices **August 15, 2002**

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Outside (Background)	325	88	54					
North Classroom 4	381	83	58	0	Y	Y	Y	Supply and exhaust off, door open, transom closed
South Classroom 5	358	84	57	0	Y	Y	Y	Supply off, exhaust –sealed, window mounted air conditioner (WAC)-off, door open
Auditorium	342	84	57	0	Y	Y	Y	Supply and exhaust off, door and window open, transom open, supply obstructed by chairs
Office Appletree	343	84	57	0	Y	N	N	Door open
Hallway	383	84	57	0	Y	N	N	Water fountain-dry trap, water damaged, plaster
104	874	79	43	4	Y	Y	Y	Supply off, exhaust sealed with cardboard, photocopier, WAC-on, dirty filter
Board of Health	877	79	44	0	Y	N	N	
Collector	847	79	44	1	Y	Y	N	Floor fan, WAC-on, exhaust in hallway (divided by wall), door open

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Williamsburg Town Offices **August 15, 2002**

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Planning	846	76	48	0	Y	N	Y	Exhaust off-to hallway
Restroom						N	Y	Exhaust into room 104
102	1068	77	47	2	Y	Y	Y	WAC, filter dirty, supply off, exhaust behind bookcase
101	985	76	44	6	Y	Y	Y	Supply off, exhaust behind file cabinet, WAC, door open
Basement	594	73	64	0	N			

*** ppm = parts per million parts of air**
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